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(19)

(54) ELECTRON DISCHARGE NOISE GENERATOR

(71) We, LITTON INDUSTRIES, INC. of 336 North Foothill Road, Beverly Hills, California, United States of America, a corporation of the State of Delaware, United States of America, do hereby declare the invention for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

The present invention relates to microwave noise generators for producing stable, noncoherent radio-frequency oscillations comprising a white noise output spectrum over a wide band of frequencies.

In the prior art, major electronic counter measures (ECM) systems consist of noise modulated continuous wave (CW) magnetrons providing spot or slow swept jamming capabilities. The noise modulation of these systems has traditionally been accomplished through the use of a noise generator, such as an electron discharge noise tube for example, in combination with an associated modulator. The modulation signal generated by the noise tube and the modulator is conventionally applied to the magnetron of such systems and generally is in the video frequency noise range, typically containing frequencies up to 5 megacycles. The resultant radio-frequency (rf) output spectrum of these prior art systems has been limited to about 10 megacycles in width at X-band for example, having an energy density of 8 to 15 watts per megacycle per second.

Traditionally the existing jamming systems have utilized the rf output spectrum of a noise modulated CW magnetron tube to effectively jam the reflected signal received by the radar receiver from the main lobe of a radar. Generally these jamming systems have employed noise modulated magnetrons which are either fixed frequency tubes or mechanically tunable tubes. Normally the fixed frequency tubes are employed for spot jamming since their output spectrum covers a very narrow frequency range, that is, once their frequency is fixed it remains substantially the same for the life of the tube. In contrast to the fixed frequency tubes, the mechanically tunable tubes, which also have a very narrow frequency spectrum at any preselected setting, are employed for swept jamming because they may be swept slowly through a wide frequency range by mechanical tuning means. Thus the tunable tubes usually provide wider frequency coverage than that offered by the fixed frequency magnetron tubes.

It is apparent from the foregoing discussion that the fixed frequency magnetrons are incapable of providing wide band frequency coverage, since they have frequency bandwiths of 5 to 10 megacycles with noise modulation, and substantially no bandwidth without the noise modulation. Thus it is also apparent that the mechanically tuned magnetrons are more effective as jammer tubes than the fixed frequency tubes, and consequently have been found to perform reasonably well in the past in ECM systems. However, it has been recognized by those versed in the ECM art that the advent of new radar designs has made it possible to obviate the actual effectiveness of such slow swept jamming techniques which employ conventional CW magnetrons that are noise modulated and mechanically tunable. The inadequacy of the mechanically tunable magnetrons arises from the fact that these tubes are inherently restricted to slow tuning means which are presently available, and that their noise spectrum is inherently narrow band.

Since the most successful prior art CW magnetrons are only mechanically tunable and therefore incapable of providing tuning rates rapid enough to insure effective jamming against the newer radar designs, it becomes obvious that any upgrading of the present ECM systems to make them substantially more effective jammers can only be accomplished through the use of a device which will enable the ECM systems to barrage jam. In this connection, barrage

jamming may be defined as that mode of operation for an ECM system in which microwave electromagnetic energy is transmitted therefrom, having a very wide frequency output power spectrum which contains power components simultaneously and constantly at substantially all frequencies within the frequency band of the output spectrum, that is designed to present a continuous curtain of noise interference to the receiver of a radar or a missile to prevent the receivers from effectively distinguishing between a desirable and an undesirable signal it may receive. Stated in another manner, the frequency range covered by barrage jamming is continuous over a substantially wide range, such that it presents to the receiver of the radar or missile an interference signal which obliterates the signal normally received by the radar or missile receiver within a frequency range common to both the radar or missile and the jammer.

In the light of the foregoing definition of barrage jamming it is apparent that neither the fixed frequency nor the mechanically tunable CW magnetrons of the prior art are capable of meeting the requirements necessary for a device to be employed in a broadhand barrage jamming ECM system. As a consequence, it is obvious that a new microwave device is needed to provide the capabilities required by barrage jamming ECM systems while simultaneously obviating deficiencies and disadvantages of the prior art CW magnetrons.

The CW magnetrons discussed hereinabove generally operate in what is commonly known in the prior art as the "coherent oscillation" region of an anode voltage versus current (VvsI) plot, where the voltage is plotted along the ordinate and the current is plotted along the abscissa. A conventional trace of such a plot starts at the origin and rises vertically along a straight line with a slight slope to a predeterminable point where it bends appreciably toward its abscissa and then continues along a straight line to a point where it is discontinued. A restricted region along the trace between the point where the trace completes its bend, commonly called the knee of the trace, and the point where it is discontinued is commonly known in the CW magnetron art as the "coherent oscillation" region of operation. In contrast to the coherent oscillation region there is another region located along the trace which is a region which begins at the knee of the trace and ends at the point where the trace completes its bend. This region is commonly known as the "noncoherent oscillation" region.

It is well known in the art that the noncoherent mode of oscillation for the CW magnetron is undesirable because it gives rise to noise, moding, and mis-starting. Operation of conventional tubes in such a region frequently results in arcing and sparking, which may burn the vanes, or alternatively, injure the cathode. Moreover, the inherent instability of conventional tubes in such non-coherent mode of oscillation may impose demands on the power supply and associated control and other equipment of an unpredictable nature, and lead to the premature failure of such associated devices.

In accordance with the invention, there is provided a microwave noise generator operable to produce stable, noncoherent radio-frequency oscillations having a white noise output spectrum over a wide band of frequencies, said generator comprising: a cathode for producing a plurality of multi-velocity electrons; a resonant anode defining an interaction space between said cathode and anode, said anode and said cathode being shaped and proportioned so as to enable a non-coherent multivelocity space charge to be provided within said interaction space to establish a noncoherent radio-frequency field including components of noise extending substantially continuously throughout said output band; and output means for deriving an output signal from said field, said output means being coupled to said anode and being such as to present with the anode to said field a substantially frequency invariant impedance of a value no lower than the minimum value sufficient to produce noncoherent oscillations for all frequencies in the output band.

In one embodiment, referred to as a "Barratron", the generator comprises a cross-field device which is capable of operating stably in a noncoherent mode of oscillation, and is characterised by a stability, efficiency of operaiton, and ease of manufacture heretofore unknown in the art. Moreover, the electro-magnetic wave output spectrum of the Barratron comprises substantially pure, incoherent white noise covering a wide frequency range, and including noise components at substantially uniform power level throughout the radio-frequency output spectrum of the generator. Such an output spectrum is achieved as an inherent feature of the generator itself, without resort to external modulators or other sources of noise. Moreover, the Barratron is self-starting, inherently stable, and displays efficiencies exceeding those of conventional CW magnetrons.

The Barratron is operated stably near the knee of its VvsI plot, in the region

commonly known as the noncoherent oscillation region, where magnetrons would operate unstably; i.e. moding, mis-starting, spurious noise, etc. In addition, the Barratron may be operated on straight direct current potential eliminating the need for traditional noise generators and modulators.

For a better understanding of the invention and to show how the same may be carried into effect, reference will now be made, by way of example, to the accompanying drawings, in which:—

Figure 1 is a diagram of a noise generator tube according to the present invention;

Figure 2 is a typical graph of the anode voltage versus the anode current illustrating operating characteristics of the tube;

Figure 3 is a plan view, partly in section, of one embodiment of a Barratron;

Figure 4 is a typical graph of electron amplitude response versus velocity distribution for a CW magnetron and for a Barratron, illustrating the distribution of electron velocities of both devices;

Figures 5 and 6 are isometric views, partly in section, of embodiments of a Barratron, according to the present invention;

Figure 7 is a typical graph of interaction impedance versus frequency response for a high Q CW magnetron and a Barratron;

Figures 8 and 9 are side views, partly in section, of other embodiments of a Barratron, according to the present invention.

Referring now to the drawings, wherein the same reference characters designate like or corresponding parts throughout the several views, there is shown in Figure 1 a diagrammatic view of a Barratron tube according to the present invention. As shown in the figure, a Barratron comprises a cathode 14 for producing a plurality of multi-velocity electrons. An anode 16 is positioned adjacent cathode 14 to receive electrons which have passed throughout an interaction space, generally designated 15, between cathode 14 and anode 16. A cross-field focussing means 13 acts on the electrons flowing through the interaction space 15 to provide a multi-velocity space charge 32 within interaction space 15 to establish a noncoherent radio-frequency power field including substantial components of noise throughout a desired output waveband within the tube. Cross-field focusing means 13 may include means for establishing a direct current potential difference between cathode 14 and anode 16, and means for establishing a magnetic field ω, generally designated 17, in planes at substantially right angles to the cathode-anode plane. A broadband loaded output means 21 coupled to the anode 16 is provided to derive an output signal from the power fields set up by space charge 32. Output means 21, together with anode 16, is tuned to present a substantially frequency invariant impedance of at least a minimum value for all frequencies in the desired output waveband to the power field. Such an impedance relationship may be most readily achieved by providing that the output circuit present a relatively heavy load to a resonant anode circuit. Anode 16 and multi-velocity space charge 32 may be re-entrant.

Considering now the operation of a Barratron tube thus described, application of a heating current from a source (not shown) to cathode 14 will cause cathode 14 to emit multi-velocity electrons. The initial velocity of the electrons will have a substantially Maxwellian distribution, where initial velocity as used herein defines the velocity possessed by an electron after surmounting the work function barrier of the cathode's surface, but before it has been affected by whatever external magnetic or electric fields may be present. The structure of the Barratron is such as to convert this random electron motion into stable noncoherent radio-frequency oscillations over a broad band of frequencies.

More particularly, electrons emitted from the cathode 14 are accelerated toward anode 16 by the potential applied thereto from crossed-field focusing means 13, and in so moving pass into interaction space 15, where they are formed into a multi-velocity space charge as a consequence of the electrostatic, magnetic and radio-frequency fields presented to the interaction space by focussing means 13, anode 16, and the motion of the electrons themselves. By appropriate adjustment of the electrostatic and magnetic fields, and the loading presented to the space charge by the anode and output means, the wide distribution of electron velocities of the electrons emitted by the cathode will persist in the space charge, and result in the production of a radio-frequency power field having a white noise power spectrum over a wide frequency range. Output means 21 and anode 16 are tuned to present a substantially frequency invariant impedance of at least a certain minimum value sufficient to produce non-coherent oscillations over the desired output waveband, and accordingly, energy is extracted from the space charge over the entire frequency response range of the output means. Thus, as the space charge generates an infinite number of noise components, the output means 21 couples energy from the field generated, and produces an output signal having a substantially uninterrupted white noise output spectrum over the wide frequency

range common to both circuit and space charge.

Adjustment of cross-field focusing means 13 to achieve stable, noncoherent oscillation may be illustrated by reference to Figure 2, which shows a typical plot of anode-cathode voltage versus current illustrating the change in current as the applied direct current potential is varied, for a particular value of magnetic field 17, with points of particular interest identified by letter. More particularly, oscillations in the Barratron mode are found to occur at values of anode current and voltage lying between points A and B on the curve. For values of applied direct current anode voltage less than those corresponding to point A, no oscillations are generated, while values of anode voltage greater than that corresponding to point B are characterized by stable, relatively noise free, coherent oscillation. Corresponding curves may be plotted for other values of magnetic field 17, which will be found to be of the same general shape as the curve depicted in Figure 2, but displaced with respect thereto. The region of Barratron oscillations may be identified on these curves in a similar manner and it will accordingly be recognized that adjustment of cross-field focusing means 13 to produce Barratron oscillations may be achieved by adjusting either the potential or the magnetic flux presented to the tube. Conventional magnetrons are operated in the region lying between points B and C on the curve, and extreme care is taken to avoid operation in the region A—B even momentarily during starting since this region, for the conventional magnetron, is characterized by the instabilities heretofore noted.

The fact that stable, noncoherent oscillations are produced by the Barratron in a region of operating potentials heretofore regarded as unstable may be attributed to the fact that heavy loading of the output structure of the Barratron results in the production of relatively weak phase-focusing fields in the tube, and accordingly, the wide velocity distribution of the electrons is retained and appears as noise in the output signal. At the same time, the reduced direct current potentials applied to the tube eliminate the tendency to arc and spark, without rendering the tube inoperative. The efficiency of the tube will be maintained however, if the anode structure presents optimum impedance to the oscillating space charge.

Those skilled in the art will readily recognize a number of structures displaying some of the above characteristics, but it will be appreciated that their use in a single tube to achieve Barratron oscillation has not heretofore been accomplished. A number of structural features have been found especially useful, and these structures will be discussed in greater detail hereinafter.

Referring now to Figure 3, there is shown a plan view of a Barratron illustrating in greater detail one form of anode structure which has been found espcially useful in mechanizing the present invention. As shown in the figure, the embodiment includes a substantially cylindrical cathode 14 for generating a plurality of multi-velocity electrons. Surrounding cathode 14 is a re-entrant anode structure 16, which includes a plurality of regularly spaced vanes 18 which project radially inward therefrom to form a plurality of cavity resonators 12. Crossed-field focusing means 13 is arranged to apply a difference of potential between cathode 14 and anode structure 16, and to supply a magnetic field in interaction space 15 defined by the circumference of cathode 14 and the circle about which the tip 28 of vanes 18 lie. Output means 21 is coupled to anode 16 to derive an output signal from the radio-frequency field set up in interaction space 15.

While the structure shown in Figure 3 bears some superficial resemblance to a conventional magnetron neither the structure, function or mode of operation corresponds thereto. More specifically, the separation between the tips of the vanes 18 designated 28 and the circumference of the cathode 14 designated 30 is of the order of 20% less than would be employed in a conventional magnetron of the prior art as given by, for example, Hull's Allis' and Hartree's equations. The separation between the vane tips 28 and the circumference 30 of the cathode 14 is determined to establish a preselected ratio of the radio-frequency electric field (Erf) to the direct current electric field (Edc) in the interaction space required for operation of the Barratron in accordance with the teachings of the invention.

As depicted in the figure, the Barratron in operation is characterized by the pressure in the interaction space of a multi-velocity electron space charge cloud 32, which may be considered to have a density distribution corresponding to the irregular shaped spoked figure shown.

The distribution of the velocities in the space charge is wide because the phase-focusing action of the r—f fields travelling in the resonant circuit is weaker than that of the more intense r—f fields of a conventional magnetron. Some of the electrons travel at speeds higher than the resonant speed while others travel at speeds lower than the resonant speed. It is the function of these multi-velocity electrons, which have a wide velocity

distribution, to contribute to the production of relatively uniform noise power density across the wide-frequency spectrum of the Barratron.

In a magnetron, on the other hand, the electron space charge within the interaction space charge is by design locked by phase-focusing in synchronous relationship with a preselected space harmonic wave travelling along the resonant anode, and the electrons form well-defined oscillating spokes within the interaction space.

The multi-velocity electrons present in the space charge of the Barratron may be attributed initially to the initial velocities of the electrons emitted from the cathode surface which have a substantially Maxwellian distribution, as heretofore discussed.

Secondly, the resonant anode has been heavily loaded to lower its loaded Q which in turn lowers its radio-frequency (r—f) fields, thereby causing the electrons to retain the wide random velocity distribution which they had on leaving the cathode. Thirdly, the closer spacing between the cathode and the resonant anode creates a stronger direct current (dc) fields, which causes the space charge to expand under the influence of the stronger dc fields, thereby providing a large space in the space charge in which to accommodate a wide distribution of electron velocities.

Referring now to Figure 4, there is shown a typical graph of electron amplitude response versus velocity distribution for a CW magnetron, curve D, and for a Barratron, curve E. As shown by curve D, the amplitude response of the electrons of a magnetron tend to fall within a narrow region centered about a resonant velocity which is proportional to the resonant frequency of the magnetrons's resonant anode, whereas, as curve E shows, the velocities of the electrons of the Barratron are generally centered at the same resonant velocity, but their distribution is much wider.

Referring now to Figure 5, there is shown an isometric view, partly in section, illustrating in greater detail one form of output structure which has been found especially useful to achieve the output loading required of Barratron operation. As shown in the figure, a plurality of cavity resonators 12 extending radially inward toward a cathode 14 are formed by a cylindrical anode block 16 and a plurality of regularly spaced vanes 18 which project radially inward therefrom. An iris 20 is formed in the cylindrical wall 22 of the anode block 16 in a region which forms the back wall of one of the cavity resonators 12. The specific configuration and size of the iris is determined by the operating frequency range of the tube and the degree of loading required between the internal resonant system of the Barratron and an external circuit load associated therewith. As shown in the figure, the aperture forming the iris 20 is centrally located within the back wall of the cavity 12 and extends therethrough from the interior wall thereof exterior wall thereof having a uniform configuration throughout. Affixed to the cylindrical wall 22 adjacent to coupling iris 20 are a pair of associated, oppositely disposed output ramps 24, only one of which is shown and an associated output horn 26 encircling said iris and enclosing said output ramps. Part of the output horn is shown cut-away so that the coupling iris and ramp may be seen more clearly.

It has been found that the efficiency of the Barratron may be considerably enhanced by providing optimum coupling between the anode and output structure and the radio frequency field set up within the interaction space. One structure which has been found especially useful to enhance the performance in such a manner is shown in Figure 6. As shown in the figure, the vanes 18 of the anode structure 16 are relatively thin, as compared to the vanes of a conventional magnetron, depicted in broken lines and designated 23. The thickness of the vanes 18 is determined by a required preselected L/C ratio which will contribute to the provision of a predetermined lower loaded Q (Q_L) for the reasonant system of the Barratron, where Q_L is defined as 2π times the total energy stored in the resonant system divided by the energy lost per cycle. Thus, the thickness may be substantially equal to 1/1000 of a wavelength at the resonant frequency of the anode. For example, at X-band it has been found that vanes having 0.010 inch thickness in a Barratron, as compared to 0.020 inch thickness in a CW magnetron, provided an improvement in performance as discussed hereinafter in greater detail.

The utility of the two elements of the Barratron discussed hereinabove will be realized by considering the functions thereof and the manner in which they cooperate with one another according to the invention. Firstly, the iris 20 is enlarged to permit a greater amount of the energy generated within the resonant system to be coupled to an associated output load through the output ramps and horn. While this increase in coupling or over-coupling as it is commonly referred to in the microwave art, would be considered undesirable in the CW magnetron, its use in the present invention is distinctly advantageous. More specifically, increased coupling in the Barratron causes the resonant anode to have a lower loaded Q (Q_L) or, stated

differently, increases the bandwidth thereof. The bandwidth of such a resonant anode may be related to the frequency and loaded Q of the anode by the following commonly known equation:

$$\Delta f = \frac{f_o}{Q_L} \qquad (1)$$

where Δf represents the bandwidth, f_o represents the resonant frequency and Q_L represents the loaded Q of the resonant anode. Thus it is seen that as the frequency remains constant and the Q_L of the anode is lowered, the bandwidth increases proportionately, partly accounting for the increased noise bandwidth provided by the Barratron. However, it should be noted at this point that the bandwidth obtainable in the Barratron is not limited by the resonant anode of the device, but is limited by the interaction which occurs between the multivelocity electron space charge and the travelling waves propagated in the resonant anode.

Several curves are shown in Figure 7, illustrating the loaded Q (Q_L) and/or interaction impedance versus frequency response for a CW magnetron, curve A; a thicker vane Barratron, curve B; and a thin vane Barratron, curve C. As shown in the drawing, the frequency response of a magnetron is concentrated in a rather restricted region about the resonant frequency (f_o) of the device, whereas in curve B, and C, which are for the Barratron, the frequency response is generally centered about the resonant frequency, but is distributed over much broader ranges.

Secondly, the vanes 18 are of the order of one half as thick as the vanes which are normally employed in a CW magnetron of corresponding dimensions and frequency. The effect of utilizing thin vanes is to raise the L/C ratio, or stated in a different manner, to lower the capacitance of each resonant cavity while simultaneously increasing the inductance thereof, thereby increasing the characteristic impedance of the resonant system. The resonant system is related to the resonant impedance in the usual manner by the equation:

$$Z_o = \sqrt{\frac{L_1}{C_1}} \qquad (2)$$

It should be noted that such a change in cavity dimensions does not appreciably change the frequency of the Barratron, which is related to the resonator reactances by the equation:

$$f_o = \frac{1}{2\pi\sqrt{L_1 C_1}} \qquad (3)$$

For a given cavity loading, therefore, an increase in characteristic impedance tends to increase the coupling between the space charge and the resonant system thereby increasing the interaction efficiency of the tube without noticeably detracting from the bandwidth as shown by curve C in Figure 7. Stated in another manner, it is well known that the highest possible impedance will provide the highest interaction or beam efficiency, so that in the present instance raising characteristic impedance of the resonant anode raises the efficiency of interaction between the resonant anode and the electron space charge.

An important advantage to be derived from the use of a Barratron resides in the fact that the quality of noise produced thereby is substantially "better" than that of prior art devices. More specifically the noise output spectrum has an infinite number of noise components distributed throughout the spectrum providing substantially uninterrupted white noise. It will be obvious to those versed in the ECM art that the provision of such a high quality noise output spectrum is far superior to the intermittent spectrum presented by the slow swept mechanically tuned devices of the prior art. Moreover, since the output spectrum is continuous, it is virtually impossible to design a radar or missile receiver which can obviate the jamming capabilites of an ECM system which utilize such barrage tubes.

It has been found that the utilization of the concepts herein set forth may be employed to provide a Barratron which has output coupling means including an iris cutout whose dimensions are 0.375 inch measured along the axis of the tube, and 0.042 inch measured in a direction perpendicular to the axis of the tube, a pair of substantially exponential output ramps which are diametrically opposite one another and disposed adjacent the iris cutout with a spacing of 0.022 inch between the ramps at the ends thereof adjacent the iris, and output horn enclosing said ramps which are affixed to the cylindrical walls of the horn. In operation a Barratron constructed with the aforesaid dimensions for X-band, with preselected dc voltage and current values has provided a fixed tuned device which generates an output power spectrum bandwidth of 300 magacycles at the one-half watt per megacycle level, and a total output power spectrum of 300 watts.

At the lower frequency of S-band, it has been found that a Barratron constructed in accordance with the basic concepts herein set forth, having a coaxial output coupler and operated with video frequency noise modulation is capable of providing an output power spectrum bandwidth of 150

megacycles at the one watt megacycle level and a total output power spectrum of 400 watts.

While the Barratron structure of the invention has been described with reference to several particular embodiments and one mode of operation, it will be understood that various modifications could be made in the construction and operation thereof without departing from the invention.

For example, there is shown in Figure 8 a modification of cross-field focusing means 13 which has been found useful in enhancing the production of a multi-velocity space charge in the interaction space. More particularly, as shown in the figure, which may be considered a side view of the Barratron shown in Figure 5, cross-field focusing means 13 includes a pair of pole pieces 34, 34′ for applying magnetic flux to the interaction space. As shown in the figure, one of the pole pieces 34 has its end face 36 slanted with respect to the end face 36′ of pole piece 34′ to produce a non-uniform magnetic field within the interaction space surrounding the cathode 14.

The variation in magnetic flux lines which thread through the interaction space encourages the provision of a wider distribution of multi-velocity electrons, as is evidenced by the equation:

$$v = \frac{E}{B} \qquad (4)$$

wherein v represents the electron velocity, E represents the electric field and B represents the crossed magnetic field strength. It is seen from the equation that as the electric field is held constant the velocity of the electrons varies as an inverse function of the magnetic field strength. It will be appreciated that the provision of a wider distribution of electron velocities will enhance the production of noise components over a wider frequency range, thereby providing an increase in the bandwidth of the noise output spectrum of the tube.

Still another embodiment of the invention is shown in Figure 9, which is a side view of a Barratron similar to that of Figure 5 but having a coaxial output for use at lower frequencies where utilization of a wave guide output would be undesirable. More particularly, as shown in Figure 9, the embodiment includes a plurality of vanes, of which only a particular one designated 48 is shown in the figure, similar to vanes 18 of the previous embodiments of the invention. These vanes are strapped together in a suitable manner by means of an outer strap 40 and an inner strap 44. The straps may be arranged to contact alternate vanes so that, for example, each vane is connected to one or the other straps 40 or 44. One of the vanes 48 to which outer strap 40 is not connected has a groove 49 therein extending along one edge of the vane, and an inner coaxial conductor 38 is arranged to pass through the groove without contacting the vane. One end of conductor 38 is connected to strap 40, while the other end of conductor 38 is arranged to pass through an aperture in anode 16, where it forms the inner conductor of a coaxial conductor including an outer conductor 42, which is connected to anode 16. The coaxial conductor formed by conductors 38 and 42 is arranged to connect the Barratron to an external load.

The coaxial output circuit thus described provides a preselected degree of heavy loading of the resonant circuit, in a manner similar to that of the coupling iris disclosed hereinabove. In operation the heavy loading of the circuit lowers the loaded Q of the circuit, for example below 100, providing broad band operation similar to that obtained with the iris 20, the ramps 24, and the output horn 26 in another preferred embodiment of the invention. The positioning of the inner conductor 38 adjacent vane 18 in this manner also prevents currents flowing in the conductor from distorting fields present within one of the anode cavities, resulting in substantially uniform loading of the entire anode.

WHAT WE CLAIM IS:—

1. A microwave noise generator operable to produce stable, noncoherent radio-frequency oscillations having a white noise output spectrum over a wide band of frequencies, said generator comprising: a cathode for producing a plurality of multi-velocity electrons; a resonant anode defining an interaction space between said cathode and anode, said anode and said cathode being shaped and proportioned so as to enable a noncoherent multivelocity space charge to be provided within said interaction space to establish a noncoherent radio-frequency field including components of noise extending substantially continuously throughout said output band; and output means for deriving an output signal from said field, said output means being coupled to said anode and being such as to present with the anode to said field a substantially frequency invariant impedance of a value no lower than the minimum value sufficient to produce noncoherent oscillations for all frequencies in the output band.

2. A generator according to claim 1 and which is a gridless self-modulated, crossed field electron discharge noise generator and

which comprises crossed-field focusing means including means for providing crossed electrostatic and electromaagnetic fields within said interaction space to interact with electrons produced by said cathode.

3. A generator according to claim 2, wherein said crossed-fields will be orthogonal.

4. A generator according to claim 2 or 3, and wherein said crossed-field focusing means includes a direct current potential source to provide, for a particular value of electromagnetic field that can be provided by the crossed-field focusing means, an electrostatic field having a value greater than that below which no oscillations take place and less than that above which coherent oscillations are produced.

5. A generator according to any one of the preceding claims, wherein the anode will present an optimum impedance to the space charge during noncoherent operation.

6. A generator according to any one of claims 1 to 5, and wherein said frequency invariant impedance is provided by a sufficiently high loading of the output means upon the anode.

7. A generator according to claim 6, wherein the Q of the anode and output means is less than 100.

8. A generator according to claim 6 or 7, wherein the output means comprises an iris aperture in the anode, a pair of ramps adjacent the iris aperture at that side of the anode remote from the interaction space, the ramps tapering in a direction away from the anode, and an output horn surrounding the ramps and being connected thereto and to the anode.

9. A generator according to claim 8, wherein the anode is resonant in the X-band and wherein the iris aperture has a maximum dimension of 0.375 inches in one direction and an orthogonal maximum dimension of 0.042 inches.

10. A generator according to any one of the preceding claims, wherein the anode encircles the cathode.

11. A generator according to claim 10, wherein the anode is cylindrical.

12. A generator according to any one of claims 1 to 11, wherein the anode is reentrant.

13. A generator according to claim 12 when appended to claim 10 or 11, wherein the anode has a plurality of regularly spaced vanes extending towards the cathode and forming a plurality of cavity resonators.

14. A generator according to claims 5 and 13, wherein each vane has thickness substantially equal to 1/100 of a wavelength at the resonant frequency of the anode.

15. A generator according to claim 13 or 14, and comprising a pair of straps connected to different pluralities of the vanes.

16. A generator according to any one of claims 1 to 7 and 10 to 15, wherein the output means are coaxial output means.

17. A generator according to claim 16 when appended to claim 13 or 14, wherein the coaxial output means has an inner conductor extending coplanar to one of said vanes and connected to a plurality of said vanes.

18. A generator according to claim 15 and 17, wherein the inner conductor is connected to one of the straps.

19. A generator according to claim 17 or 18, wherein the inner conductor extends through an aperture in a wall of the anode and through a groove in the vane with which it is coplanar, the inner conductor not being in electrical contact with the anode material defining the aperture and the groove.

20. A generator according to any one of the preceding claims and having means able to establish a non-uniform magnetic field in the interaction space.

21. A generator according to claim 20, wherein the means able to establish a non-uniform magnetic field comprises two pole pieces having pole faces at respective opposite sides of the interaction space, said pole faces lying in non-parallel planes.

22. A generator according to any one of the preceding claims and which is in operation with such a field in said interaction space that the output means delivers noncoherent radio-frequency oscillations having a white-noise spectrum over a wide frequency band.

23. A noise generator substantially as hereinbefore described with reference to Figures 1 and 2, or Figures 3 and 5 or Figure 6, or Figure 8 or Figure 9 of the accompanying drawings.

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1600235 COMPLETE SPECIFICATION

2 SHEETS This drawing is a reproduction of the Original on a reduced scale

Sheet 1

Fig. 1

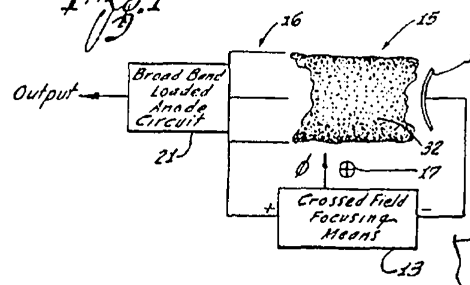


Fig. 3

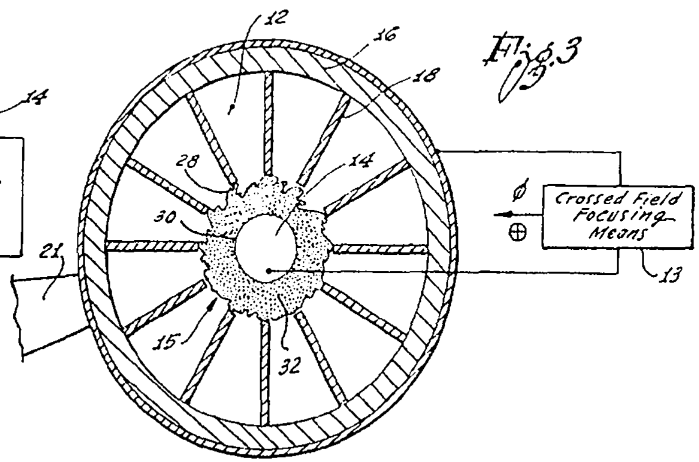


Fig. 2

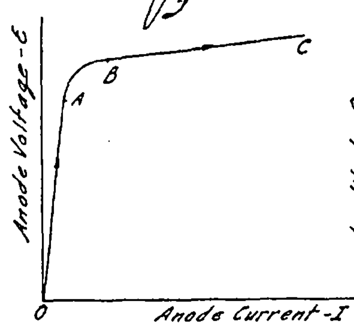


Fig. 4

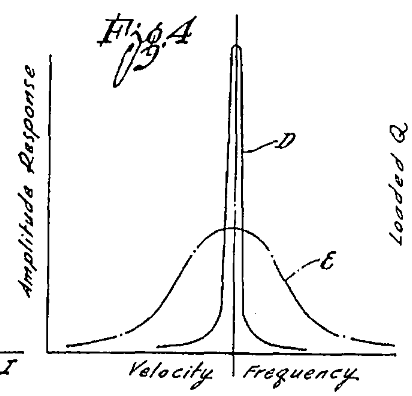
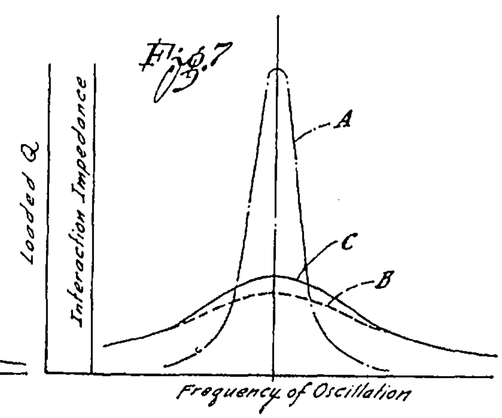


Fig. 7



1600235 COMPLETE SPECIFICATION
2 SHEETS This drawing is a reproduction of the Original on a reduced scale
Sheet 2

Fig.5

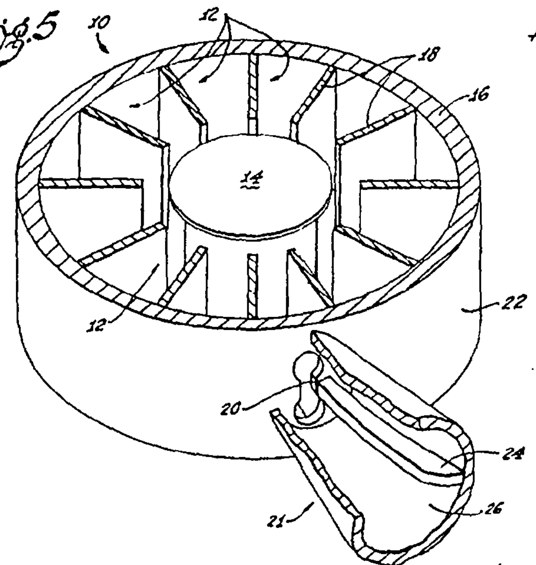


Fig.6

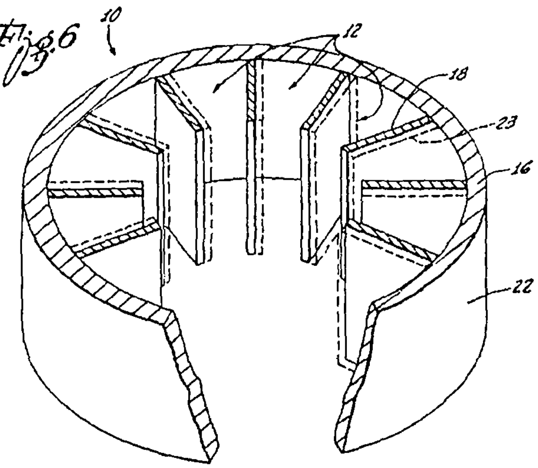


Fig.8

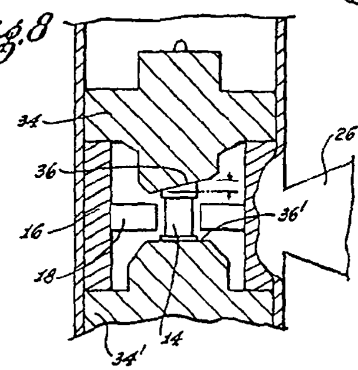


Fig.9

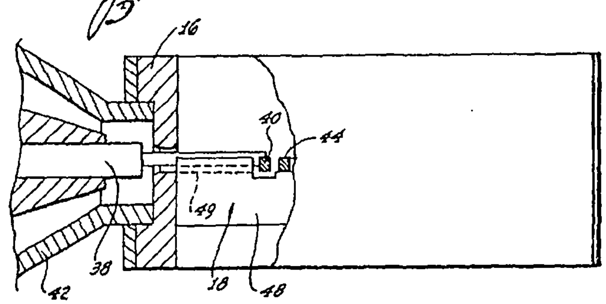


Fig. 1

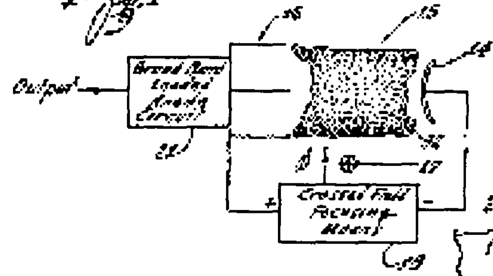


Fig. 3

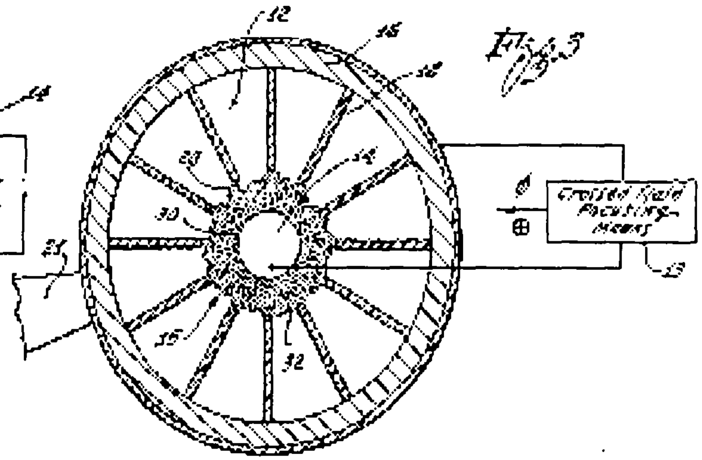


Fig. 2

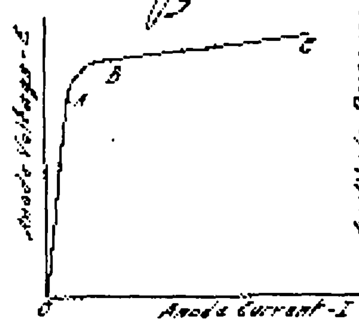


Fig. 4

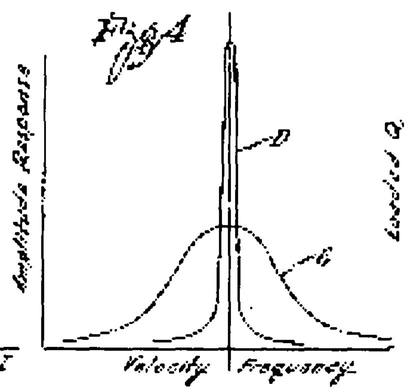


Fig. 7

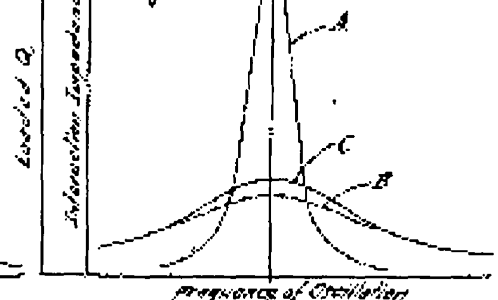


Fig. 5

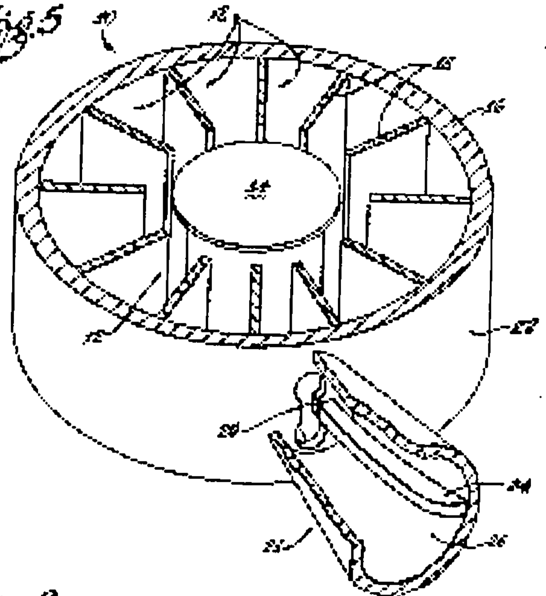


Fig. 6

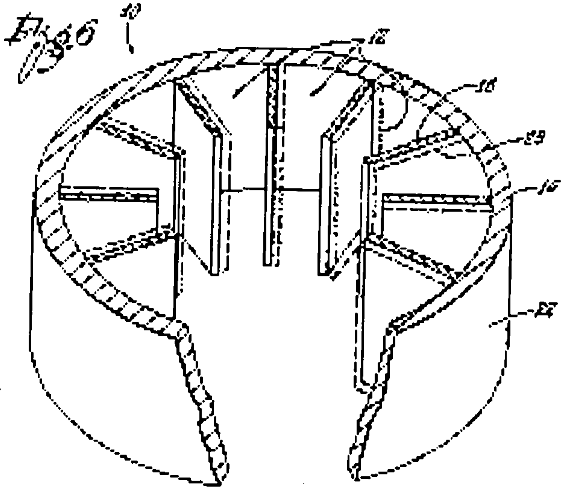


Fig. 8

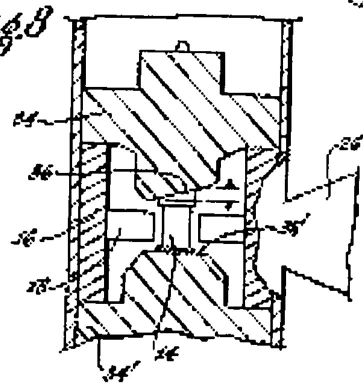


Fig. 9